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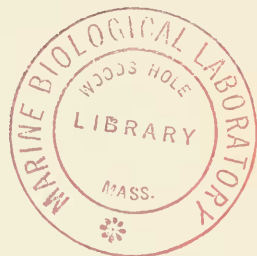
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Balanus hopkinsi, New Species, and *B. balanus*
(Linnaeus, 1758) (Cirripedia, Thoracica) from
Plio-Pleistocene Sediments on Tjörnes,
Northern Iceland

By

Victor A. Zullo

California Academy of Sciences



ABSTRACT: *Balanus (Balanus) hopkinsi*, a new species bearing close resemblance to *B. eburneus* Gould, 1841, occurs in the Tjörnes sediments of late Pliocene or earliest Pleistocene age on Tjörnes, northern Iceland, where it is associated with a temperate Atlantic molluscan fauna. The overlying early Pleistocene Breidavík sediments contain the boreo-arctic barnacle *B. (B.) balanus* (Linnaeus, 1758) in association with extant molluscs of a colder water aspect.

INTRODUCTION

A collection of barnacles made in the course of a re-study of the Pliocene and Pleistocene sediments of Tjörnes in northern Iceland (fig. 1) by Thorleifur Einarsson, Icelandic University Research Institute and David M. Hopkins, United States Geological Survey, Menlo Park, California, includes a new species of *Balanus (Balanus)* and *B. balanus* (Linnaeus, 1758). The species are mutually exclusive in their stratigraphic distribution throughout the sequence (fig. 2). *Balanus balanus*, an extant boreo-arctic barnacle, occurs in the Breidavík sediments of early Pleistocene age together with a molluscan fauna characterized by species of Pacific ancestry and cold water aspect. The new species occurs in the stratigraphically lower Tjörnes sediments of late Pliocene or earliest Pleistocene age. These deposits are below the earliest indication of glaciation in the sequence (2.4–3.0 million years ago) and contain a number of

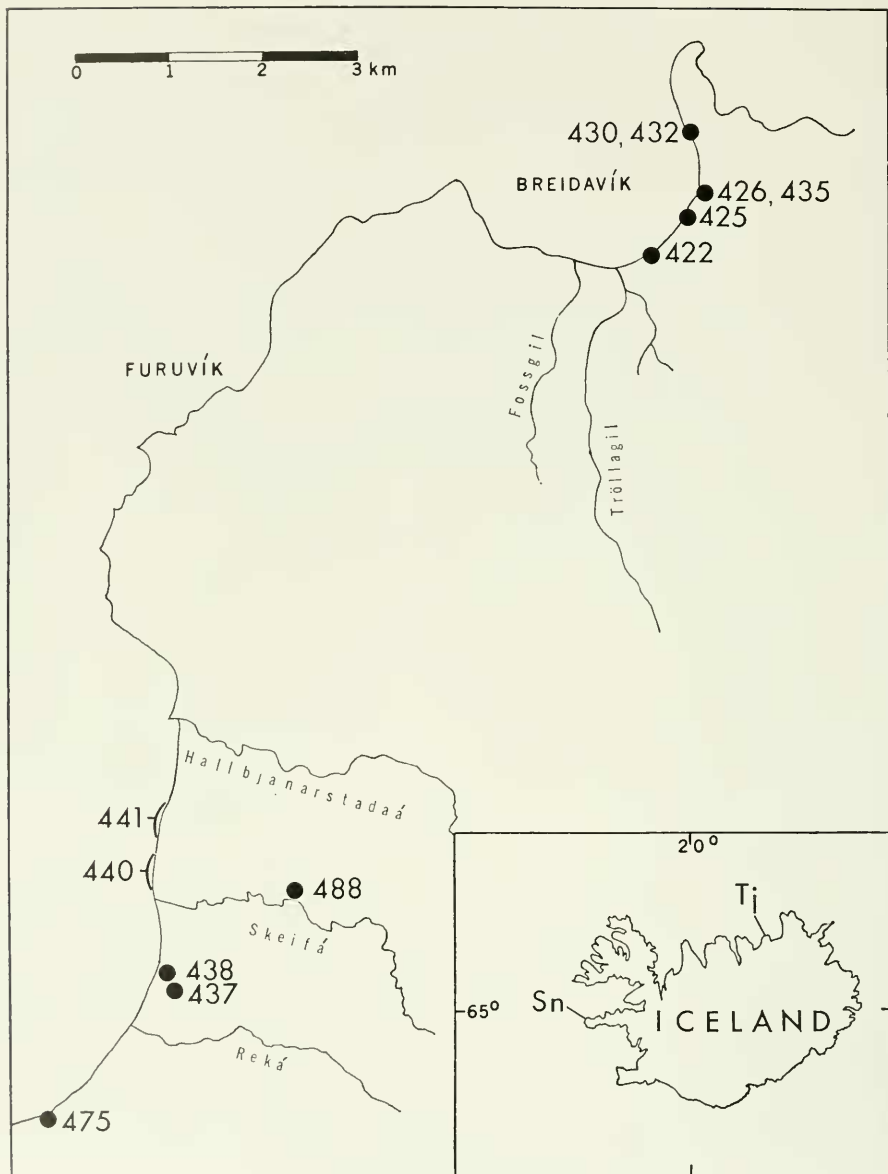
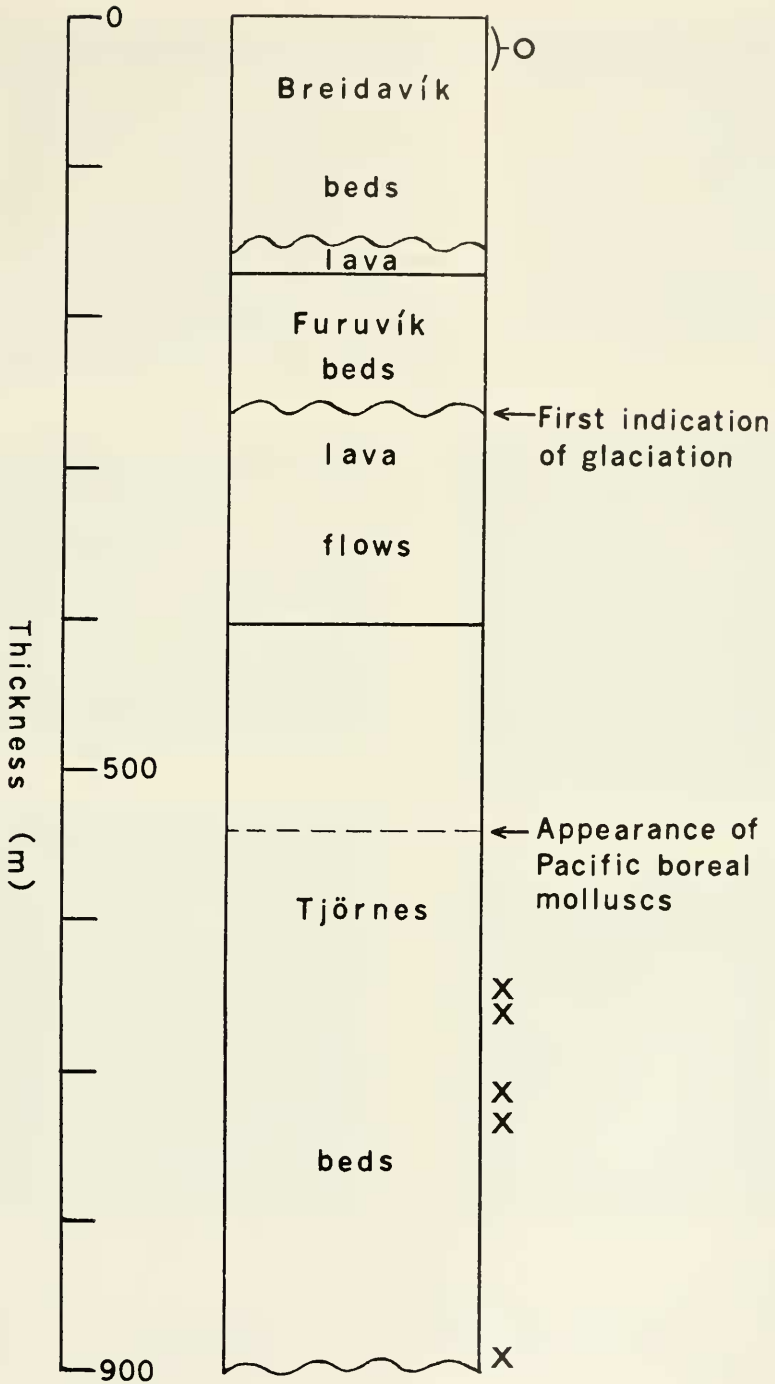


FIGURE 1. Map of barnacle localities on Tjörnes peninsula, northern Iceland. Inset indicates location of Tjörnes (Tj) and Snæfellsnes (Sn) in Iceland.

FIGURE 2. Part of Tjörnes sequence illustrating stratigraphic distribution of *Balanus balanus* (○) and *B. hopkinsi* (×) (modified after Einarsson *et al.*, 1967).



molluscs whose northern limits are now to the south (Hopkins *et al.*, 1965; Einarsson *et al.*, 1967). This new species is described as follows:

Balanus (Balanus) hopkinsi Zullo, new species.

(Figures 3-10.)

DIAGNOSIS. Smooth walled, conic *Balanus* strict sense, with broad radii, transversely septate parietal and basal tubes, strongly arched scutum with external longitudinal striae, and trident shaped tergum with long, narrow, pointed spur.

DESCRIPTION. Shell (figs. 9-10) high conic to tulipiform, strongly bent towards short, acutely concave carina; orifice diamond shaped, toothed, as broad or broader than base; parietes smooth, with numerous ovate longitudinal tubes crossed throughout by closely spaced transverse septa; radii broad with denticulate sutural edges and oblique summits that make about a 45° angle with direction of growth; alae broad with less oblique summits; interior sharply ribbed below sheath; basis calcareous, with transversely septate tubes.

Scutum (figs. 5, 7, 8) strongly warped between base and apex; exterior with conspicuous growth ridges crossed by fine, but obvious longitudinal striae; striae best developed over narrow, pigmented longitudinal bands sometimes present on lower two-thirds of scuta (fig. 8); adductor ridge short, straight, erect, placed about midway between articular ridge and occludent margin; upper end of adductor ridge higher than and not confluent with or approaching articular ridge; articular ridge broad, one-half to two-thirds length of tergal margin, reflexed; no depressor muscle pit observed.

Tergum (figs. 3, 4, 6) trident shaped, flat; carinal side of basal margin with deep, V-shaped notch; scutal side similarly, but less deeply notched; tergal spur long, narrow, about one-fifth width of basal margin, and terminating in acute point on scutal side; depressor muscle crests well developed on carinal lobe.

MEASUREMENTS

	lateral diameter	carinorostral diameter	rostral height
Paratype USNM 161401	17 mm.	19.4 mm.	18.7 mm.
Paratype USNM 161403 (conic)	14 mm.	15 mm.	21.1 mm.
Paratype USNM 161402 (tulipiform) about	10 mm.	13 mm.	31 mm.

OCCURRENCE. Specimens of *B. hopkinsi* were collected at the following six localities in the Tjörnes sediments (after Hopkins, personal communication, 1964):

475B Bed A of Bárðarson (1925). Landslide block on south bank
(Type Locality) of the mouth of Kaldakvisl, representing the lowest bed in



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FIGURES 3-8. *Balanus (Balanus) hopkinsi* Zullo, new species. (3) Tergal interior, (4) tergal exterior, (5) scutal interior, Holotype (USNM cat. no. 161398; loc. 475B), height of tergum 8.5 mm; (6) tergal exterior, (8) scutal exterior, Paratype (USNM cat. no. 161399; loc. 475B), height of tergum 8.2 mm; (7) scutal exterior, Paratype (USNM cat. no. 161400; loc. 488B), height of scutum 9.5 mm.

- the Tjörnes sediments, resting unconformably on Tertiary basalts, 66° 86.3' N, 17° 17.5' W.
- 438E *Balanus horizon* supposedly at top of Bed 7, but because of landsliding possibly part of Bed 8, Lindarlaekjarfoss, 66° 07.1' N, 17° 15.9' W.
- 437 Base of Bed 8, just above coal bed D, swale halfway between Lindarlaekur and mouth of Reká.
- 488B Bed 9, west end of cutbank on north side of Skeifá, just upstream from road, 66° 07.7' N, 17° 14.0' W.
- 440B Bed 9, between Skeifarfoss and Brunngil, 66° 07.5' N, 17° 16.0' W.
- 441B Middle and upper part of Bed 10, Stollen, 66° 07.9' N, 17° 15.9' W to 66° 08.25' N, 17° 15.8' W.

DISPOSITION OF TYPE MATERIAL. Holotype and paratypes deposited in the U. S. National Museum, Washington, D. C. Holotype USNM cat. no. 161398 and paratypes USNM cat. nos. 161399, 161402, 161403 from locality 475B. Paratype USNM cat. no. 161401 from locality 440 B. Paratype USNM cat. no. 161400 from locality 488B.

REMARKS: *Balanus hopkinsi* is similar and no doubt closely related to the extant western North Atlantic species *B. eburneus* Gould, 1841 that ranges from Rio de Janeiro north into Massachusetts. The new species can, however, be readily distinguished through comparison of the opercular valves. The scutum of *B. eburneus* is nearly flat and strongly striate longitudinally, whereas that of *B. hopkinsi* is markedly arched and the striae, although distinct, are less deeply incised in all specimens examined. The adductor ridge of the scutum is also differently placed in the two species. In *B. eburneus* the apical end nears or is confluent with the basal end of the articular ridge, but in *B. hopkinsi* the adductor ridge is removed from the articular ridge and apically terminates higher on the scutum. The tergal spurs are quite different. That of *B. eburneus* is relatively short, broad, and is basally truncate, whereas the new species has a longer, narrower spur that is pointed basally.

The shell and terga of the West African species *B. pallidus* Darwin, 1854 (including *B. pallidus stutsburi* Darwin, 1854) are somewhat similar to those of *B. hopkinsi*, but the scuta of the former lack longitudinal striae.

***Balanus (Balanus) balanus* (Linnaeus).**

(Figures 11, 12.)

Balanus balanus occurs in glacial deposits of the upper part of the Breidavík sediment sequence on Tjörnes and the lower part of the Búlandshöfði sediment sequence of Snaefellsnes, western Iceland (fig. 1). These deposits are stratigraphically higher than the rocks containing *B. hopkinsi* and succeed an



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FIGURES 9-10. *Balanus (Balanus) hopkinsi* Zullo, new species. (9) High conic shell, Paratype (USNM cat. no. 161401; loc. 440B), height 17.5 mm; (10) tulipiform shell, Paratype (USNM cat. no. 161402; loc. 475B), height 31.4 mm.

FIGURES 11-12. *Balanus (Balanus) balanus* (Linnaeus). (11) Shell, Hypotype (USNM cat. no. 161405; loc. 426B), carinorostral diameter 15.2 mm; (12) basis on rock, Hypotype (USNM cat. no. 161404; loc. 435B), greatest diameter 29.3 mm.

influx of boreal molluscs of Pacific origin. Remains of this barnacle were obtained from the following eight localities in Iceland:

Breidavik sediments, Tjörnes

- 432B From scree blocks on beach derived from Beds 12 and 14 near Torfhóll, 66° 12.0' N, 17° 09.0' W.
- 430B Scree block probably derived from base of Bed 14, but possibly from Bed 12. On beach at Torfhóll, 66° 12.0' N, 17° 09.0' W.

- 432F From 1 m of Bed 14, Torfhóll, 66° 12.0' N, 17° 09.0' W.
 426B Conglomerate bed at base of Bed 12 just north of Svarthamar, 66° 11.7' N, 17° 08.7' W.
 435B Same locality as 426 B.
 422C Bed 9 in shore cliffs between Tröllagil and Svarthamar, 66° 11.3' N, 17° 09.5' W.
 425B Bed 8b at Svarthamar, 66° 11.5' N, 17° 09.0' W.

Bulandshöfði sediments, Snaejellsnes

- 536B Búlandsgil sediments exposed in dry waterfall back of small electric power plant at Ólafsvík. Specimens are from upper and lower claystone, in iceberg sediment formed near icefront, 64° 53.3' N, 23° 42.0' W.

Extant *B. balanus* is a boreo-arctic species ranging from 80° North latitude to Long Island Sound and the English Channel in the Atlantic, and Puget Sound and the Kurile Islands in the Pacific, from the lower intertidal (in northern waters) to about 300 m depth (Broch, 1924; Pilsbry, 1916). This species (= *B. porcatus* of authors) has been reported from several Pleistocene localities in northern Europe and North America, including the Red and Mammaliferous Crags of England, the glacial deposits of Udevalla, Sweden, Skien, Norway, Island of Bute, Scotland, and eastern Canada (Darwin, 1854), Spitzbergen and Greenland (vide Feyling-Hanssen, 1953), and late Pleistocene terrace deposits in Oregon and glacio-marine sediments in southeastern Alaska (Zullo, 1966). *Balanus balanus* was previously reported from the Pleistocene of western Iceland by Bárðarson (1921) together with *B. crenatus* Bruguière, 1789 and *Balanus* species.

The numerous Tertiary reports of *B. balanus* from Europe are open to question. Kolosváry (1955, p. 184) listed it from the Miocene of Italy, England, France, Germany, the USSR, Belgium, and Sweden, and Davadie (1963, p. 69), in repeating these localities, stated that this species is common in the Pliocene of Italy and Sicily and abundant in the lower Helvetian of France. Kolosváry's list of Miocene localities must in part be a typographical error, for there are no known marine deposits of definite Miocene age in England. This record, together with that from Sweden, probably was meant to refer to Darwin's (1854) Pleistocene localities. Few of the Tertiary specimens referred to *B. balanus* have been illustrated, and the only ones to come to my attention (those of Alessandri, 1906, pl. 17, figs. 16-17, and Menesini, 1966, pl. 26, figs. 3-7) from the Miocene and Pliocene of Italy are definitely not of that species.

It is quite possible that most, if not all of the Tertiary identifications of *B. balanus* are incorrect. Certainly Miocene hydroclimates of Europe were quite warmer than the boreo-arctic waters to which extant *B. balanus* is restricted. Hence, if the Miocene records were assumed to be correct, it would

force the conclusion that this species had lived first under one, then another set of climatic conditions, had markedly altered its physiological tolerances to meet these climatic changes, but had maintained its morphological identity. In view of this seemingly untenable set of circumstances, it is suggested that a more critical examination be made of the Tertiary barnacles assigned to *B. balanus*.

ZOOGEOGRAPHIC IMPLICATIONS

The distribution of barnacles in the sequence on Tjörnes follows the paleoclimatic and zoogeographic conclusions presented by Einarsson *et al.* (1967). *Balanus hopkinsi* occurs exclusively in the lowest "Tapes" zone and the middle "Mactra" zone which are typified by shallow water and littoral sediments intercalated with thin lignite seams and lacustrine beds. The molluscs of these zones are primarily Atlantic in character, but include a few warm water species of Pacific origin that are postulated to have taken advantage of a Miocene opening of the Bering land bridge to migrate via the northern Arctic route. This molluscan fauna and the pollen flora of the lignites suggest a milder temperate climate than is present in Iceland today.

The upper "Cardium" zone of the Tjörnes sediments is characterized by an influx of boreal molluscs of Pacific origin and a corresponding elimination of the species typical of the lower zones. The first indications of glaciation in the Tjörnes sequence (2.4–3.0 million years ago) are found in the Furuvík beds which consist of a sequence of marine and glacio-marine sediments interbedded in the lavas separating the Tjörnes and Breidavík sediments. No barnacles were collected either from the "Cardium" zone or the Furuvík beds, but the modern boreo-arctic species *B. balanus* was obtained from the stratigraphically higher Breidavík sediments. These sediments are composed of interbedded lavas and glacial deposits that contain a modern boreo-arctic molluscan fauna.

It is impossible at present to determine whether *B. hopkinsi* is part of the ancestral stock group of extent *B. eburneus* or a diversification from *B. eburneus* itself. Fossils ascribed to *B. eburneus* are few (*e.g.*, Pilsbry, 1918, 1924) and being based on shells alone, are not conclusive. It is possible to hypothesize that *B. hopkinsi* was of Atlantic origin and was eliminated from northern Iceland by the cooling of marine hydroclimates preceding glaciation.

If the Tertiary European records of *B. balanus* can be ignored, it is tempting to suggest that this species was part of the major invasion of Pacific marine invertebrates into the boreal Atlantic during the periodic Pleistocene inundations of Bering land bridge. However, the Pacific fossil record of *B. balanus* is scanty and undiagnostic, and although it has a potential ancestor in the Pacific *B. rostratus* Hoek, 1883 stock, much more information is needed before any conclusion can be made concerning the origin of *B. balanus*.

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